Economical Analysis of the Cold Air Distribution System: A Case Study

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Abstract: In this paper, we briefly introduce the super cold air distribution technique. By comparing the schemes of two air conditioning systems, including a modified air conditioning system, this paper analyzes the technique parameters and the economics of the cold air distribution system in detail. The detailed analysis includes the air quality, comfort index, initial cost, life cost, static recycle period, and dynamic recycle period. The advantages and trends of super cold air distribution systems in the future are pointed out. The economical analysis and technical comparison is based on real data. The conclusion is useful for the design of super cold air conditioning systems of large shops and office buildings.

Key words: super cold air distribution； technique parameters； economical analysis

1．INTRODUCTION

Recently, in the commercial buildings, the ice storage system has obviously helped the building owner reduce the expense of energy consuming. Besides, it will save the operating cost more by taking full advantage of the chilled water available with ice storage to reduce the temperature of the air supply.

The technology of cold air distribution appeared firstly in 1947, at that time it was limited in some special occasions. In 1980s, people found there were some virtues by reducing the temperature of the air supply after they took interested in the ice storage main function is commerce, official working and food and beverage. The 4th storey underground is the system again. From 1990s, people have done series of researches about thermal comfort, cooling coil pipe, terminal units, the temperature of the air supply and so on which make the forms and designs of cold air distribution combined with ice storage more diversiform and perfect. The superiorities of cold air distribution combined with ice storage have been approbated by more and more people. With the endeavors of various sections, lots of special equipments which is low energy consuming and great performance have been successfully exploited.

Along with the development of ice storage technology, the advantages of cold air distribution combined with ice storage system (reducing the electric demand at peak on, lowing operational cost, saving floor-to-floor height and so on) have aroused many people’s attention. At present, the examples with cold air distribution combined with ice storage system is HangZhou constructing bank, the national electric power attempered center, commercial town of underground in western ZhongGuanCun and so on.

2．PROJECT SUMMARY

2.1 General Situation of Architecture

The Cultural Commercial building lies in ZhongGuanCun area, it is a comprehensive skyscraper, amounts to 17 storeys on the ground, 4 storeys of underground, the total height of the building is 74.40m, and the area is 10,520m 2. Its garage and goods and materials storehouse partly which is for people's air defense in wartime, the 3rd

storey underground is the garage, the 2nd storey underground is for the garage, heating power station, refrigeration station and transformer substation, the 1st storey underground is for restaurant, kitchen, water supply substation, reclaimed water station, fire control pond and the pump house, indoor bicycle parking area, etc… From 1st floor to 10th floor is a commercial part, the main function is for the selling and wholesale of the books, from 11th floor to 17th floor is for official working.

2.2 The Air-condition Design Plan

The air-conditioning area of the Cultural Commercial building is 9,700 m^2, cold load is 12,530Kw that is 3,564 tons of refrigeration, because there is only a road between the Culture Commercial and the cooling plant in Western ZhongGuanCun, the owner of this building decided to utilize the cooling source which is offered by ZhongGuanCun cold substation instead of building cold substation for the chilled water by itself. In order to take full advantage of the latent energy that the ice storage system offers, the indoor air-condition design changed from conventional system to cold air distribution system.

The areas designed are divided into inner zone and outer zone. According to their plane function, the rooms near the external walls are divided into the outer zone; other areas belong to the inner zone. Cooling is needed in the inner zone during the whole year; but cooling needed in summer and heating needed in winter in the outer zone. The outer zone of commercial part adopted all-air of low temperature system, the temperature of chilled air changed to 8 ℃ from original 13 ℃. The second chilled water is 2.2 ℃/ 13.3 ℃ which is supplied by the cooling plant. Because the construction have already basically finished, in order to reduce the workload for transforming of designing and constructing, inter zone adopts fan coil system adding fresh air as before, the second chilled water is 7 ℃/ 12 ℃ which is supplied by the cooling plant too. The outer zone of official working part adopts the cold air distribution with ultra-low temperature VAV-box. The interior district of official working part adopts the fan coil system adding fresh air. Air blows out from top and return to top entirely. Because the inter zone needs long-term cooling, double pipes system is adopted.

3. COMPARED WITH CONVENTIONAL AIR CONDITIONING SYSTEM

3.1 Analysis of Technical Parameters

Indoor design parameters are as follows: dry bulb temperature is 25 , relative humidity is 45%, and enthalpy value is 47.86 kJ/kg. Tab.1 compares cold air distribution (scheme 2) with conventional system (scheme 1).

We can find out from Tab.1 that the enthalpy between air supply and air return in scheme 1 is nearly as twice as in scheme 2. On the assumption that the load of the room does not change, the air necessarily dealt with is nearly half of original. Analysis of the psychrometric chart can be seen in Fig.1 and Fig.2 respectively. (Point ‘1’ in the picture is the dew point of air supply, point ‘s’ is the state of air supply, point ‘n’ is the indoor state, point ‘h’ is the mixed point of flesh air and return air, point ‘w’ is the outdoor air state.)

From the analysis of technical parameters, we learn that cold air distribution can lead to smaller ductwork, smaller supply fans and less terminal units by increasing difference in temperature and reducing the air flow relatively. Literature [4] has made a detailed analysis. The original design and the new scheme on partial areas of the second floor will be compared and analyzed below. Please see Fig.3 and Fig. 4 separately about the idiographic analysis.

Tab.1 Comparison of technical parameters

Contrastive item	Scheme 1	Scheme 2
Temperature of supply/return water	7℃/12℃	2.2℃/13℃
Temperature of air supply	13℃	8℃
Relative humidity of air supply state	90%	90%
Enthalpy value of air supply state	34.3kJ/kg	23.13kJ/kg

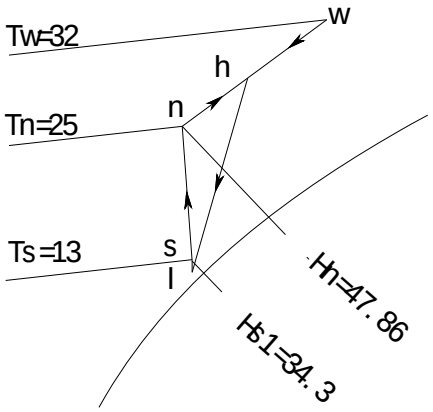

Fig.1 Analysis of psychrometric chart in the air supply process about Scheme 1

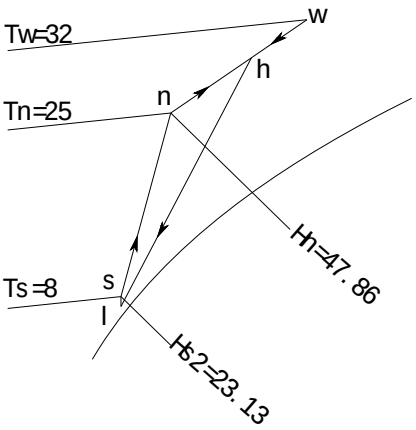

Fig. 2 Analysis of psychrometric chart in the air supply process about Scheme 2

Tab.2 Comparison of the parameters of the AHU in the second floor

Numbering of equipment	Scheme 1		Scheme 2	
	Air quantity (m^3/h)	Power (kW)	Air quantity (m^3/h)	Power (kW)
KT-2-1	10000	3.6	4000	1.1
KT-2-2	12000	4.4	6000	2.0
KT-2-3	10000	3.6	5000	1.1
KT-2-4	12000	4.4	6000	2.0
KT-2-5	12000	4.4	6000	2.0
KT-2-6	12000	4.4	6000	2.0
Summation	68000	24.8	33000	10.2

Tab. 3 The expend of terminal units of conventional air conditioning system

Item	Quantity	Unit price	Total prices	Remark
Air duct	1021 (m^2)	25～50 Yuan/ m^2	32,100 Yuan	Insulation thickness 19 mm
Insulation of air duct	19.4 ($m^{3)}$	1500 Yuan/ m^3	29,100 Yuan	
Diffuser	118 (unit)	370 Yuan per unit （in average）	43,700 Yuan	
Summation	/	/	104,900 Yuan	

3.2 Economic Analysis

3.2.1 The cost of terminal units

Compares and analyses the terminal units of conventional air conditioning system and cold air distribution system in the case of the second floor.

From the comparison of Fig.3 and Fig.4, we can

find that, under the same cold load, the size of air duct in scheme 2 is smaller than that in scheme 1 and the diffusers in scheme 2 is less. The air quantity supplied by KT-2-2 is 12000m^3/h in scheme 1 and 6000 m^3/h in scheme 2. Tab.2 lists the comparison of the parameters of the AHU on the whole second floor. The cost of terminal units in these two schemes is given in the Tab.3 and Tab.4.

Tab.4 The expend of terminal units of cold air distribution system

Item	Quantity	Unit price	Total prices	Remark
Air duct	327 m^2	25～50 Yuan/ m^2	10,000 Yuan	Insulation thickness 32 mm
Insulation of air duct	9.82 m^3	1500 Yuan/ m^3	14,700 Yuan	
Diffuser	71 unit	2200 Yuan per unit （in average）	156,00 Yuan	
Summation	/	/	181,000 Yuan	

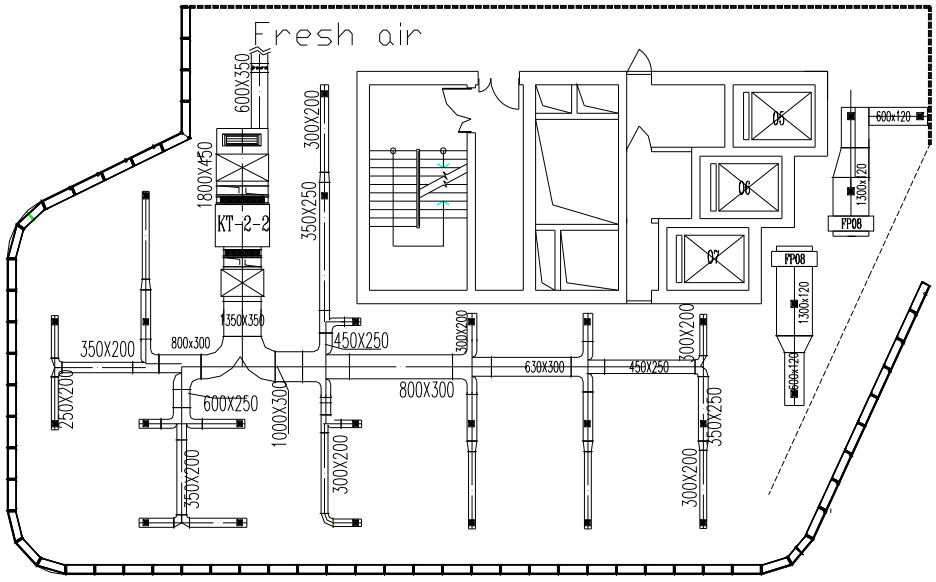

Fig. 3 Air duct ichnography of partial area on the second floor of scheme 1

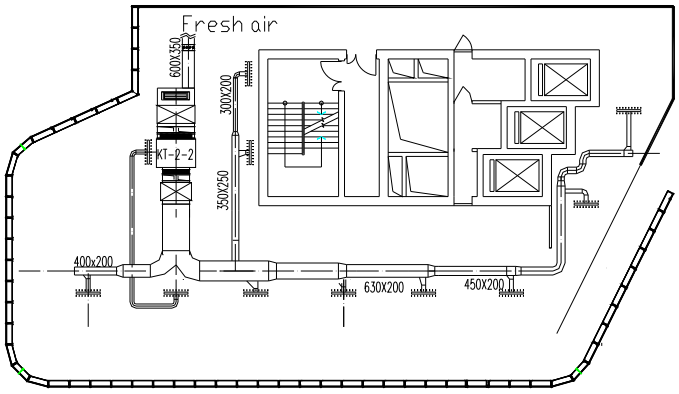

Fig.4 Air duct ichnography of partial area on the second floor of scheme 2

The Tab.3 and Tab.4 show that the cost of terminal units of cold air distribution system is great because of the expensive diffuser used specially in cold air distribution. In view of the especial demand

for the terminal units and the guarantee for the indoor comfort, this design for cold air distribution system chose the diffuser which is mature at abroad.

After calculation, the total expend of terminal units of scheme 2 is 10,086,000 yuan which is 2,731,000 yuan more than that in scheme 1(7,355,000yuan). The details are listed in Tab.5.

3.2.2 Operating cost

The operational cost of cold air distribution is lower due to the less air flow supplied. The Tab.2 shows that the air flow supplied in cold air distribution system is 49% and power consumption is 41% of scheme 1. The operational cost of one year is 2,262,000 yuan in scheme 1, while is 1,364,500 yuan in scheme 2 with estimation. Comparison of the operational cost of commercial part only consider the AHU, without the equipments (such as extract fans) which are not altered; while consider the terminal units of VAV, fan coil and energy recovery ventilator in the office building part. The operational cost is calculated according to the operational time per day and operational days of one year. The detailed calculation isn't carried out in here.

3.2.3 Compositive comparison

Comparing the initial investment and the operating cost of the two projects, the payback period of cold air distribution system comparing to the conventional air conditioning system is 3.4years. Concretely calculating as follow tab.6. According Tab.6, the Total present value becomes positive value after the forth year, and then the operation cost of scheme 2 is less 710,200 yuan than that of scheme1. So the economic benefit of cold air distribution is very evident for the culture center building.

4. CONCLUTSIONS

(1) From the comparing and analyzing ibid, Ice storage cold air distribution system has ascendant economic characteristic, calling for the cold air distribution system of 4℃～9℃ combing with ice storage system can decrease energy cost by a long way, and saving operation cost for the owner;

(2) The special diffuser selected is expensive, which make the initial cost increase. In fact, with the studying of cold air distribution technology going deep into gradually and constantly trying, the cost of cold air distribution terminal will be lower and lower. So the advantage of cold air distribution technology will be more evidence. Therefore, the research and develop of terminal units is the bottleneck of cold air distribution technology development in China.

(3) The concept of district cooling will be accepted by us gradually, and the low temperature cold resource will be easily gained, we can get cold resource of 3.3℃～12℃ without any initial investment. Which makes the cold distribution technology applying become wider, and cold air distribution and ice storage combine easily.

Tab. 5 Economic comparison of cold air distribution system and conventional system

No.	Item	Scheme1	Scheme2
1	The cost of air conditioning unit(Yuan)	1,591,300	1,909,600
2	The cost of diffuser(Yuan)	436,600	2,824,800
3	The cost of VAV-box terminal(Yuan)	/	1,470,000
4	The cost of energy recovery ventilator(Yuan)	2,110,000	1,710,000
5	The cost of fan coil(Yuan)	1,319,500	640,500
6	The cost of main duct of chilled water (Yuan)	429,600	264,300
7	The cost of insulation for the main duct of chilled water(Yuan)	81,000	66,600
8	The cost of duct of chilled water(Yuan)	486,700	408,800
9	The cost of insulation for the duct of chilled water(Yuan)	101,400	97,100

10	The cost of air duct(Yuan)	418,600	250,400
11	The cost of insulation for the air duct(Yuan)	380,200	444,300
The total cost of infrastructure (Yuan)		7,355,000	10,086,000
Operational cost (Yuan per year)		2,261,800	1,364,500

Tab.6 The present value of cold air distribution system comparing to the conventional air conditioning system

items \ years		0	1	2	3	4	5	6
Scheme1	The initial cost of the terminal(yuan)	7.355,000	0	0	0	0	0	0
	The operation cost(yuan)	0	2,261,800	2,318,300	2,376,300	2,435,700	2,496,600	2,559,000
Scheme1	The initial cost of the terminal(yuan)	10,086,000	0	0	0	0	0	0
	The operation cost(yuan)	0	1,364,500	1,398,700	1,433,600	1,469,500	1,506,200	1,543,900
Net value(yuan)		-2,731,000	897,200	919,700	942,700	966,200	990,400	1,015,200
Net present value rate:8%		1.00	0.9259	0.8573	0.7938	0.7350	0.6806	0.6302
Net present value(yuan)		-2,731,000	830,800	788,500	748,300	710,200	674,000	639,700
Total present value(yuan)		-2,731,000	-1,900,200	-1,111,800	-363,400	346,800	1,020,800	1,660,500

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